Some Microscopic Distinctions between Good and Bad Timber of the Same Species. By Dr. J. T. Rothrock.

(Read before the American Philosophical Society, February 2, 1883.)

A cross section of one of our ordinary "hard woods" shows, more or less conspicuously, pores which are known as ducts, and which from their relatively large size are distinctly visible to the naked eye; secondly, it shows much smaller pores which may, or may not, require the magnifying glass to detect, and whose walls constitute the woody fibre of the stick; thirdly, we should have (assuming the specimen to be an exogen), the annual rings which mark, *as a rule*, the limit of each year's growth; fourthly, there would be the radial lines extending from the centre outwardly to the bark, these being the medullary rays or the so-called "silver grain."

If, on the other hand, the specimen under observation were one of our ordinary cone bearing trees, the ducts would be wanting, and the mass of the section would be composed of woody fibre. There may be openings which will resemble the ducts in hard wood, but instead of showing regularly organized walls, these will be found to represent simply openings left by the destruction or the separation of the woody fibres. They are by no means so numerous ordinarily as the ducts in an average "hard wood stick."

Considered from the standpoint of resistance to longitudinal strain, the strength-giving element of wood is the woody fibre; and other things being equal, it is strong in proportion as the fibre walls are relatively thick, and the fibre cavities relatively small. Illustrating this, we have the following cross sections of wood fibres, all magnified 242 diameters: 1, is that of Abies subalpina (Pumpkin Pine) from Utah; a timber which is almost worthless; 2, is that of our American Linden; 3, represents the Butternut (or Juglans cinerea); 4, is the Pig-nut Hickory (or Carya porcina) and 5, is that of an average specimen of White Oak fibre (Quercus alba). Considering the areas of the cavities in each of these sections, the White Oak has about six times as much wood in its walls, as there is in that of the Pumpkin Pine—a fact which it must be allowed will go far toward explaining the differences in the strength of the two woods. It is true that there may be differences in the strength of wood which are due to the molecular differences involved in the structure of the fibre, but with these we are probably in no position to deal. The intercellular substance which is destroyed by boiling in nitric acid and potassium chlorate is to a certain extent an element in the strength of wood. There can be no doubt but that it aids in increasing the friction between the individual fibres, and is therefore the chief agent by which these are bound together, and thus resist longitudinal strain. So far as my investigations go, there is less relation between length of fibre and strength, than there is between thickness of fibre wall and strength. Some woods acquire additional strength, both longitudinal and transverse, from a twisting of the wood fibres among themselves. The Rock Elm is a notable example of this among our larger trees; as the Viburnum nudum or Withe-rod is among the shrubs.

So far as the ducts are concerned, while the material of which they are composed may be quite as strong as that of the fibres, yet owing to the enormous cavity they contain, it is apparent that as compared with fibres, they must be much weaker; that in fact every duct is to be regarded as an element of weakness to the stick. Hence then, other things being equal, the more fibres and the fewer ducts, the stronger is any given stick of timber as compared with another of the same species.

The question of durability in exposed positions is quite another thing, and has no close relation to strength.

Accepting the above facts as proven, mere examination of a cross section of timber with the naked eye, or at most with an ordinary hand lens, may afford a reasonably safe way of estimating the quality of a given specimen of wood.

Associated with the appearance presented by the ducts, and the mass of fibres, is another element of structure, *i. e.*, that of the annual rings. These are usually caused as may be seen (A and B 6) by the thick, flat cells which are formed in autumn as contrasted (A and B 7) with the larger ones which mark the first growth of the ensuing spring. The number of rows which are thus flattened in the autumn wood is by no means constant. Sometimes, as in the case of the White Oak, there being but two, three or four; or as in the case of the Chestnut being often about eight, or more; or as in the Redwood of California (Sequoia sempervirens) as high as fifteen. As a rule the color in all these autumn fibres is deeper than in those made earlier. Hence both shape and color combine to mark the "year's growth."

The term "year's growth" is one which should not be depended upon too absolutely, inasmuch as it is well known to be misleading at times. Thus, in the American Linden, one frequently sees a ring more on one side than on the other; and indications are not wanting, which would prove that very frequently several such rings may form in our latitude in a single season.

There are some facts of practical importance connected with the wood formed during the season, or to speak more accurately, with all the tissue lying between the denser, flatter fibres which are assumed to be formed in the autumns of two successive years. In White Oak, as shown by figures A and B, there may be a great range in the distance between these zones of flat fibres. Thus fig. B shows that the growth for the year was about twice that shown by fig. A. The former of these figures represents a good specimen of White Oak, and the latter a bad one, each having been carefully tested for strength by competent mechanical experimenters. In these instances the reason for the difference in the quality of the wood is obviously in the relative predominance of solid woody fibre over open ducts in the good specimen (B), and the lesser quantity of wood as compared with ducts in (A), the bad. It so happens that in A the diameter of the duct (.01430 of an inch) is greater by far than in the better wood. This can, however, hardly be regarded as constant. What does appear to prevail in White Oak is, the fact that most of these *large* ducts are made early in the season, and that whether much or little wood is subsequently formed the number of the ducts will not greatly vary. Hence, then, for White Oak we may assert that the specimen with the larger year's growth is, other things being equal, the better. Very frequently two duct cavities are thrown into one, so that the width is greatly increased. These may usually be distinguished from true ducts by the irregular and disintegrated walls, which serve to explain the process by which the size was attained.* The above rule, as to the relation between size of "year's growth" and value, in Oak I have made the subject of some investigation, taking as test cases specimens of timber upon whose value opinions had been given by the most competent workers in the wood.

Hickory, good and bad (certainly Carya alba and C. porcina), involves another element than mere size of the annual ring. Though I must here add that the best bit of C. porcina I have ever seen was also one that had the largest year's growth I had ever seen. In this wood (Hickory), the large ducts are not so clearly limited in their production to the early part of the season (especially if the stick be one of poor quality), but are, or may be, clearly scattered through the wood. And the quality of the wood is determined mainly by the number and size of these ducts. Thus in bad Pig-Nut Hickory (C. porcina) I find in a surface of a quarter of an inch square, sixty-five, each with an average size of .01428 inch ; as against twenty-seven ducts having an average width of .01224 inch in good Hickory of the same species.

To a greater or less extent the same statements, as to cause of difference between good and bad qualities of Chestnut, and Locust (Robinia pseudacacia), will apply.

Figure C. illustrates the marked tendency which the ducts have to be associated in Hickory. It also shows the effect of the growth in pushing aside one of the medullary rays, 9 b. It is not uncommon, however, in this wood to find these rays broken by the growth of the duct, and in Oak this is still less rare. I have frequently seen specimens of bad White Oak which were as porous as the average Red Oak, the ducts being, as shown by the micrometer, quite as great in their diameter.

The medullary rays or "silver grain" appear also to have important relation to value of Oak certainly, and probably of Hickory, to say nothing of other kinds of timber. The fibres and ducts are ordinarily characterized as the vertical system from the line in which they are elongated. With equal propriety then the medullary rays are spoken of as the horizontal system of the plant, because they are elongated at right angles to the fibres and ducts. From the thick walls of the cells constituting these rays, we might suppose they had to do with the lateral strength of the timber. This view is *partially* confirmed by a microscopic examination of the cross section of the different woods ; as upon the whole, Red-wood, Chestnut and White Pine show either that these rays are fewer in number or less strongly

---

* Very often this process of disintegration of the wall may convert a true duct into a mere cavity without walls.

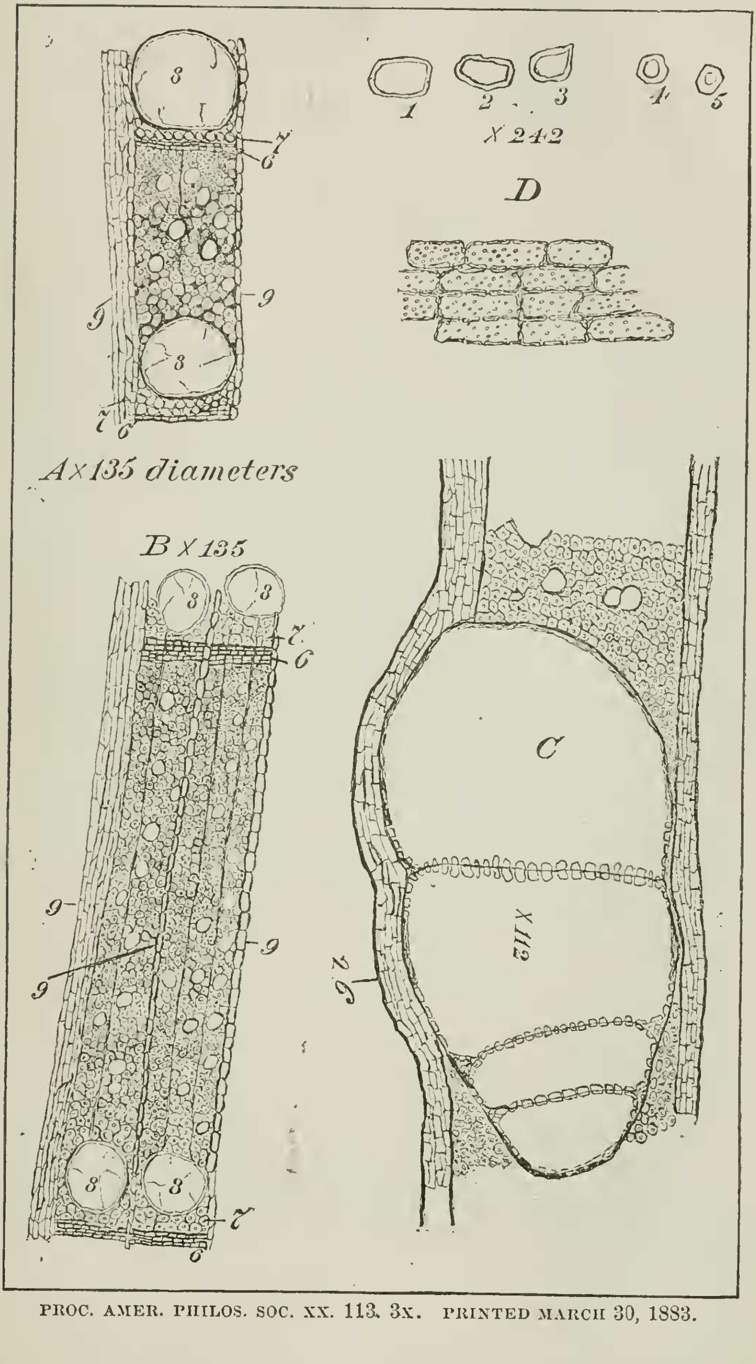
developed than in the Tupelo (Nyssa multiflora), or in a specimen of good White Oak. However, in making comparisons of this kind, we must be careful to make them at points equidistant from the centre ; and to note whether these rays extend to the centre, or only part way in from the bark toward the heart of the tree, as this latter circumstance determines their age, and also generally their relative strength. In such species of timber as have rays extending vertically over two or more inches, as in some of the Oaks, the ray often indicates the line of easiest splitting, as is often seen by the effect of drying upon the exposed end of such timber. This is not an invalidation of the statement that one function of the rays appears to be to give lateral tenacity, *i. e.* to such portions of solid wood as lie between the rays. They form as it were a chain binding the periphery to the centre, but offer no resistance to the separation of one woody wedge which they outline, from another such wedge which is placed alongside. If this be so, then such specimens of wood as have the rays ruptured by encroachment of ducts or by any process of disintegration would be correspondingly weakened. It is furthermore worthy of note that in such specimens of good White Oak (Quercus alba), and good Pig-Nut Hickory (C. porcina) as upon actual trial had proven to be the best, these rays were as a rule either most numerous, or best developed, or both.

Examined microscopically, the cells making up these rays present an appearance when viewed from the side like figure D. That is to say they are quadrangular, thick walled and with numerous thin places in which the primary cell wall may or may not remain. Their very appearance suggests a somewhat easy communication between those (cells) which are adjacent, and thus afford a probable explanation of the fact, that when the starch made in summer by the younger portion of the tree is being conveyed into the interior of the branches for winter storage, these rays appear to furnish the most available avenues for accomplishing the work, and micro-chemical tests show that it is most abundant in them. While these thin or open places in the cells of the medullar ray usually communicate with each other, it is remarkable that they are much fewer in the sides toward the ducts and fibres.

It would be exceedingly interesting to know how far the facts indicated by this paper would conform to the value of timber as determined by specific gravity.

EXPLANATION OF ILLUSTRATIONS.

1. Cross Section of Abies subalpina wood fibre × 242.
2. " " Tilia Americana " " × 242.
3. " " Juglans cinerea, " " × 242.
4. " " Carya porcina, " " × 242.
5. " " Quercus alba " " × 242.
6. A and B. Flattened cells made in autumn.
7. " " Larger cells which indicate growth of following spring.
8. " " Open ducts seen in cross section.
9. " " Medullary rays.


8
7
6
9
9
8
7
6
A × 135 diameters
1
2
3
4
5
× 242
D
B × 135
8
8
7
6
9
9
9
8
8
7
6
C
× 112
2
2

A. Cross section of bad White Oak × 135.
B. " " good " " × 135.
C. " " Carya porcina × 112, grouping of ducts and pushing aside of Medullary rays.
D. Fragment of Medullary ray showing the pits or pores in the walls, × 300.

An improvement in the construction of the Hypsometrical Aneroid. By Dr. Persifor Frazer.

(*Read before the American Philosophical Society, March 2, 1883.*)

While in France last year the idea occurred to the writer to lessen the weight of the delicate Hicks Barometer by constructing as much as possible of it of aluminium. Supposing that this could be done without difficulty, though of course at an increased expense, the writer devised a case of cork to contain it, and wrote to Mr. Hicks of London asking him to make the attempt. After a number of interviews it was finally estimated that the cost of the new form of aneroid should not exceed £10, or just double that of the ordinary instrument of brass in a wooden case. Delays were experienced from the beginning and added very much to the expense of the instruments when they finally arrived here.

First it was found difficult to produce an aluminium dial plate with a graduation of the requisite delicacy and accuracy. Then the internal supports could not be easily cast in that metal of the shapes necessary to build the frame for the more delicate moving parts.

Finally the writer was obliged to leave England without having received the barometers. When they arrived a few days ago the Government duty on them was $30.40 a piece, added to which Mr. Hicks had found it necessary to increase the original charge of £10 to £15 apiece. In consequence they cost a little over $105 apiece.

They are, however, creditable to Mr. Hicks's workmanship, and if their manufacture should increase, could no doubt be obtained at a very much reduced price.*

In order to prevent the breaking of the cork, by friction on the clothing, a light canvas cover was added, weighing 50 grams.

The following is a comparison of the weights of the ordinary Hicks barometer with one of them.

	Old form.		New form.	
Case and strap,	400 grams.	(wood)	150 grams.	(cork)
Aneroid,	1000 "	(brass)	400 "	(Aluminium)
Canvas cover,	——		50 "	
Total weight,	1400 "		600 "	
" "	or 3.09 lbs. (av.)		1.323 lbs. (av.)	

The ordinary instrument weighs, therefore, 2⅓ times as much as the new form, the weight of the old case being closely that of the new barometer.

---

* A letter received from Mr. Hicks, after the above was in print, reiterates the difficulties with which he contended, and states that notwithstanding the experience gained in making mine, he cannot deliver them for less than £15 apiece.